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COMPARATIVE VISUAL PERFORMANCE WITH ANVIS AND AN/PVS-5A NIGHT VISION GOGGLES UNDER STARLIGHT CONDITIONS

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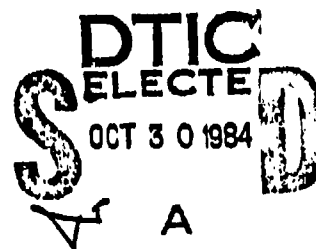
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August 1984

Interim Report for Period September 1983 - March 1984



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This report has been reviewed and is approved for publication.

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Experimental testing of 10 subjects wearing the AN/PVS-5A (II GEN) night vision goggles (NVG) and ANVIS (III GEN) NVG was conducted under field conditions of ambient starlight illumination ($\approx 10^{-5}$ mL). The parameters measured were: 1) binocular visual acuity (BVA), 2) stereopsis (depth perception), and 3) a subjective forced choice test. Results showed that BVA was 20/124 and 20/36 for the II and III GEN NVG, respectively. This difference was statistically as well as clinically significant. The stereopsis test results were inconclusive and variable because of the limited sample size and relative inexperience of the subjects in using NVG. Neither BVA nor stereopsis with the NVG was found to be related to standard baseline measures of these parameters in the clinic. Even though the ANVIS has better gain, resolution and sensitivity, 6 out of the 10 subjects preferred the AN/PVS-5A for viewing the subjective test. This seemingly paradoxical finding was surmised to be a result of the presence or lack of scene contrast due to the differential sensitivities in the II and III GEN photocathode tubes.					
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COMPARATIVE VISUAL PERFORMANCE WITH ANVIS AND AN/PVS-5A
NIGHT VISION GOGGLES UNDER STARLIGHT CONDITIONS

INTRODUCTION

United States Air Force (USAF) night flying missions are presently receiving considerable attention for several reasons. First, it is known that the concept of continuous combat is fundamental to Soviet doctrine. The Soviets consistently train during nighttime, and their weapon systems are equipped with sophisticated devices to enhance their night fighting capabilities (1). Secondly, in some parts of the world (e.g., Europe), nighttime conditions are present for almost three-quarters of each day during the winter. Thirdly, if tactical air power is to correct the big imbalance that exists between our ground and armored forces, and those of the Soviet Union, it cannot be limited to just a part-time role. Therefore, it is essential that the USAF maintain an around-the-clock operational capability with great emphasis on night operations.

The Ophthalmology Branch, of the USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, has initiated a program to extensively study night visual performance. The objectives are to develop a simple, rapid, and accurate night vision screening device; establish norms for flying personnel; evaluate training and enhancement techniques; determine the effects of various drugs; and investigate image intensifying devices (i.e., night vision goggles (NVG)). This program is the initial phase of the NVG investigation.

Previous studies (2, 3, 4, 5) of man/NVG visual function have produced a wealth of information, but new questions have arisen because of the recent advent of a III generation (GEN) NVG. This new device, dubbed Aviator's Night Vision Imaging System (ANVIS) (Fig. 1), is reported (6, 7) to possess improved performance capabilities over the AN/PVS-5A (II GEN) NVG (Fig. 2), including the ability to adequately function at very low ambient light levels. Unfortunately, much of the past research had been conducted under relatively bright illumination levels that may no longer be appropriate for ANVIS night missions. Therefore, the primary objective of this experiment is to measure visual performance with NVG under starlight illumination (10^{-5} mL), which is considered to be a minimal light level conducive to safe night operations (7, 8).

The parameters chosen to quantify man/NVG visual performance were visual acuity and stereopsis (depth perception). These two clinical measures were selected because they are sensitive psychophysical indicators of visual function and, unlike the more commonly used engineering specifications (Table 1), are more easily related to by clinical and flight personnel.

To ensure realism, this experiment was conducted in an outdoor, field environment so that the actual spectral illumination of the night sky would be obtained rather than using artificial lighting created in the laboratory. Both AN/PVS-5A and ANVIS devices were tested under these conditions, to obtain comparison performance levels. The reason for including the AN/PVS-5A NVG is

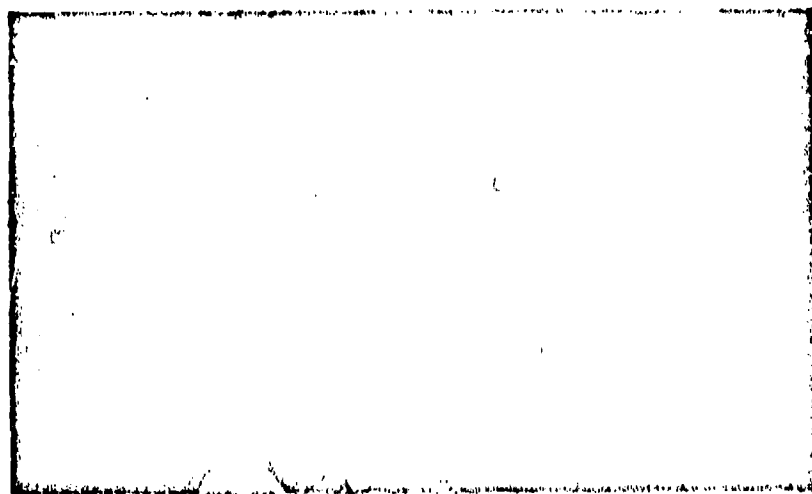


Figure 1. ANVIS (III GEN) night vision goggles.

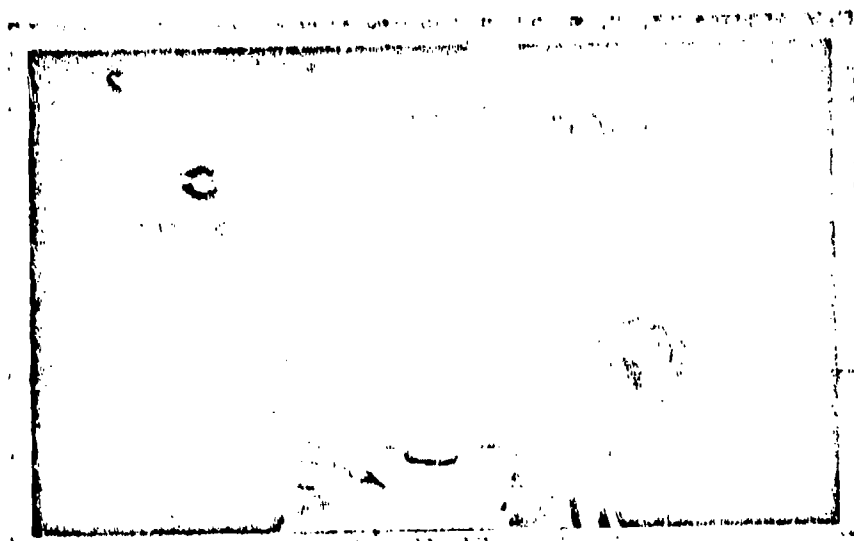


Figure 2. AN/PVS-5A (II GEN) night vision goggles.

TABLE 1. NOMINAL SPECIFICATION OF AN/PVS-5A AND ANVIS NVG.

	II GEN (AN/PVS-5A)	III GEN (ANVIS)
GAIN	10,000	25,000
RESOLUTION	24 lp/mm	36 lp/mm
I/NUMBER	1/1.4	1/1.2
PHOTOCATHODE RESPONSE		
.83 μ m	15 mAMPS/WATT	100 mAMPS/WATT
.88 μ m	0	600 mAMPS/WATT
MAG	1:1	1:1
FIELD OF VIEW	40°	40°
FOCUS RANGE	10" TO INFINITY	10" TO INFINITY
DIOPTER ADJUSTMENT	+2 TO -6	+2 TO -6
INTERPUPILLARY DISTANCE	55-72 mm	52-72 mm
OUTPUT (.53 μ m)	.5 mL	1.0 mL
POWER	2.7v LITHIUM	3.0v LITHIUM (2) (OR 28v VDC)
LIFE	10 HRS	30 HRS
WEIGHT	30 oz	16 oz
MOUNTING	HEADSTRAPS WITH SNAPS	HELMET MOUNT

that it will probably remain in the USAF active inventory for many years before the ANVIS completely transitions on line (8). Both types of NVG will continue to be operationally used; therefore, differences in performance must be understood. In addition, a subjective comparison of AN/PVS-5A and ANVIS performance was incorporated within the experimental paradigm.

DESCRIPTION

Night vision goggles are the modern offspring of the infrared (IR) rifle and sighting scopes spawned by the military in World War II. Originally intended for ground troops, they have been adapted by the U.S. Army for use by helicopter pilots; and recently, the USAF is studying their potential in fixed-wing aircraft.

These binocular electro-optical devices function by amplifying existing light by means of two-image intensifier tubes. The ambient light entering these tubes is focused by the objective lens onto a photocathode which is receptive to visible and near IR radiation. The differential sensitivity of the AN/PVS-5A and ANVIS photocathodes is shown in Figure 3. It can be seen that the response of the AN/PVS-5A is about equal between 0.5 μm (blue-green) and 0.85 μm (IR). The ANVIS, on the other hand, has a blue-green cutoff but extends a little more into the IR; of significance is its greatly enhanced sensitivity in the red and near IR end of the spectrum.

Photons of light striking the photocathode cause a release of electrons which, in turn, cause a cascading emission of multiple secondary electrons within the adjacent microchannel plate. An electric field then guides these electrons to the phosphor screen and produces an amplified light image. The output of the phosphor screen is a relatively narrow band peaking at 0.53 μm (Fig. 4). Thus, the image is green, and color discrimination of objects is not possible. An automatic brightness control limits the maximum luminance of the phosphor screen to -0.5 mL in the AN/PVS-5A NVG, and -1.0 mL in the ANVIS, to prevent output surges and minimize light adaptation. A clamp voltage mechanism is present to protect against excessively bright light sources (e.g., flares, search lights, etc.). Finally, this amplified image is made upright by a fiberoptic inverter and viewed through the eyepiece lens.

Although satisfactory for infantry use, the AN/PVS-5A was criticized by aircrew for its poor low-light level performance, frequent battery failures, and heavy weight. But, the major problem with the AN/PVS-5A, as seen in Figure 2, was its large faceplate which severely limited peripheral vision; did not allow easy near-distance focus; and was not compatible with helmet-mounted sighting systems, visors, or protective masks. In addition, flight spectacles could not be worn concurrently so those aviators with significant astigmatism were handicapped with reduced vision (9). This is because the dioptic focusing mechanism of the NVG, which goes from +2 to -6 diopters to neutralize spherical refractive errors, will not correct astigmatism errors. However, many of these shortcomings have been overcome by the widespread adoption of the faceplate modification (10, 11) (Fig. 5), which provides a "look under" capability and is compatible with flight spectacles.

The helmet-mounted ANVIS, shown in Figure 1, is considered to possess many electro-optical improvements over the AN/PVS-5A (Table 1, Figs. 3, 6). In addition, the basic ANVIS design: 1) is compatible with eyeglasses, visors, and masks; 2) has a "look under" capability that allows normal peripheral vision which can be used to monitor the flight instruments; 3) has a fail-safe battery system with warning light; and 4) weighs less and is counterbalanced more easily. The single most important technical feature is its greater low-light level performance (i.e., sensitivity). The ANVIS tube profoundly outperforms the AN/PVS-5A tube because of the improved operational efficiency in the red and IR region of the spectrum (Fig. 3). The end result is much greater contrast when viewing objects illuminated by starlight, hence, greater system resolution and longer detection ranges (Fig. 7).

The addition of blue-green cockpit lighting to aircraft allows ANVIS users many other advantages (7). The ANVIS tube is less sensitive in the blue-green end of the spectrum shown in Figure 3. By adding a minus blue filter to the optical system, this device becomes virtually blind to blue-green light. On the other hand, the response of the human eye is greatest at night in the blue-green region (12) making cockpit instruments easy to read even at very low intensities. The cockpit and instrument panel can be easily seen by the unaided eye looking under or around the NVG; while the ANVIS, unaffected by internal glare and wind screen reflection, responds best to outside lighting which in starlight is mostly red and IR (Fig. 8). Therefore, mixing ANVIS and blue-green cockpit lighting achieves a great many advantages. It should be mentioned, however, that the minus blue filter modification is not compatible with the symbology in some Head-up Displays (HUDS) (13).

METHODOLOGY

Ten subjects were selected and baseline visual acuity and stereopsis (depth perception) measurements were obtained before experimentally testing with the NVG. The baseline data was taken so that any correlative relationship with NVG field performance could be ascertained. Visual acuity was tested binocularly using standard Snellen letters projected at 20 ft. Stereopsis was measured by testing with a Howard-Dolman apparatus set at 20 ft and finding the mean linear displacement of 5 trials (14).

The equation:

$$\eta = \frac{2a\Delta b}{b^2} \times 206,000$$

where: η = sec of arc of retinal disparity; $2a$ = interpupillary distance; b = testing distance; and Δb = mean linear displacement, was used to convert the data to angular displacement in seconds of arc. Subjects needing optical correction for distance vision were required to wear eyeglasses for all testing during the experiment with one exception; subject 9 wore contact lenses.

The field tests with the NVG were conducted at a remote location in the South Texas Hill Country which provided absolute darkness except for the ambient sky illumination. The experiments were conducted on 2 different nights from 1900-2200 hrs. No moonlight was present. Both nights were similar with slightly overcast starlight conditions.

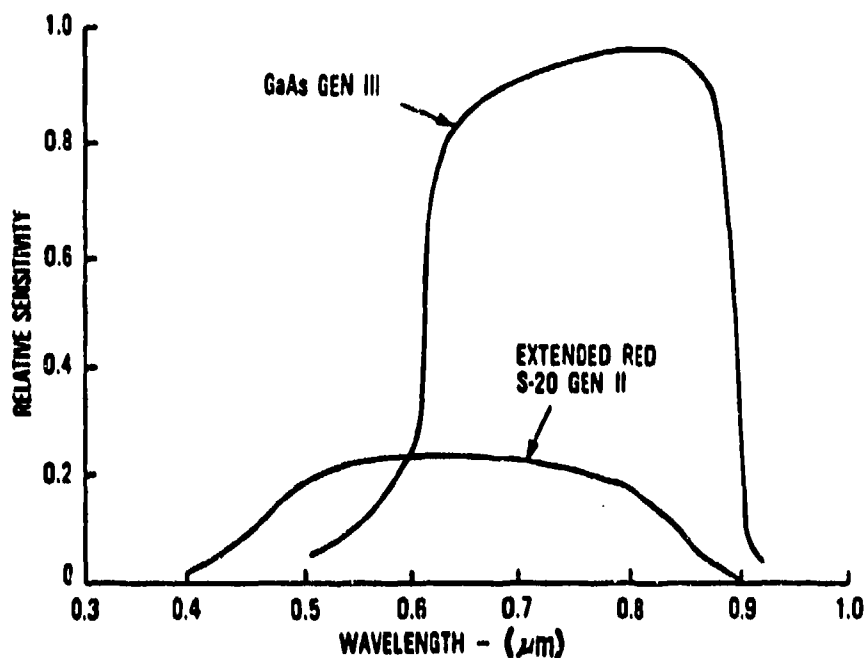


Figure 3. Sensitivities of intensifier photocathodes.

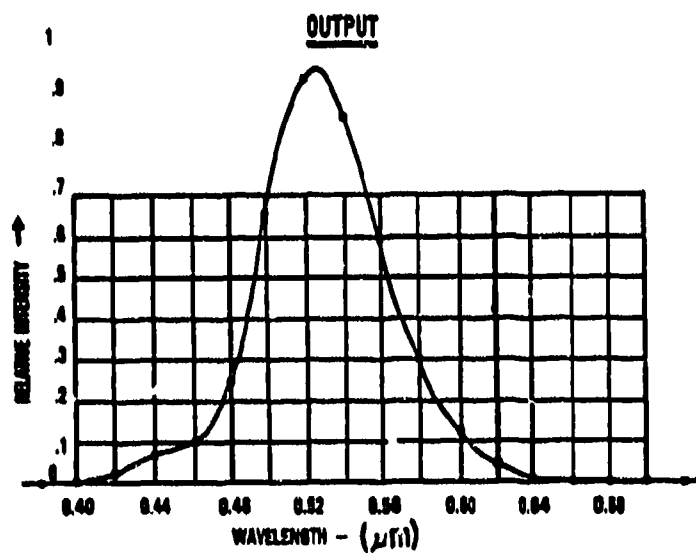


Figure 4. Relative spectral output of the NVG phosphor screen.



Figure 5. Modified AN/PVS-5A faceplate with helmet mounting and counterbalance weight.

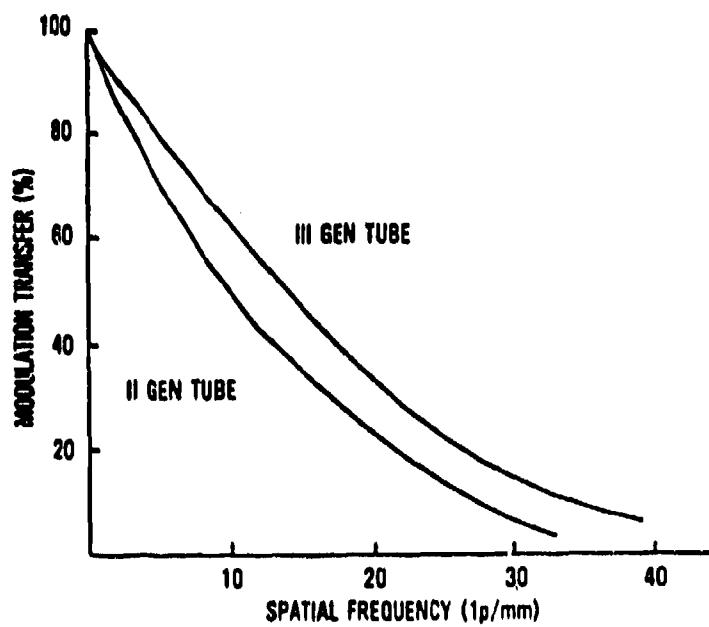


Figure 6. Image tube MTF.

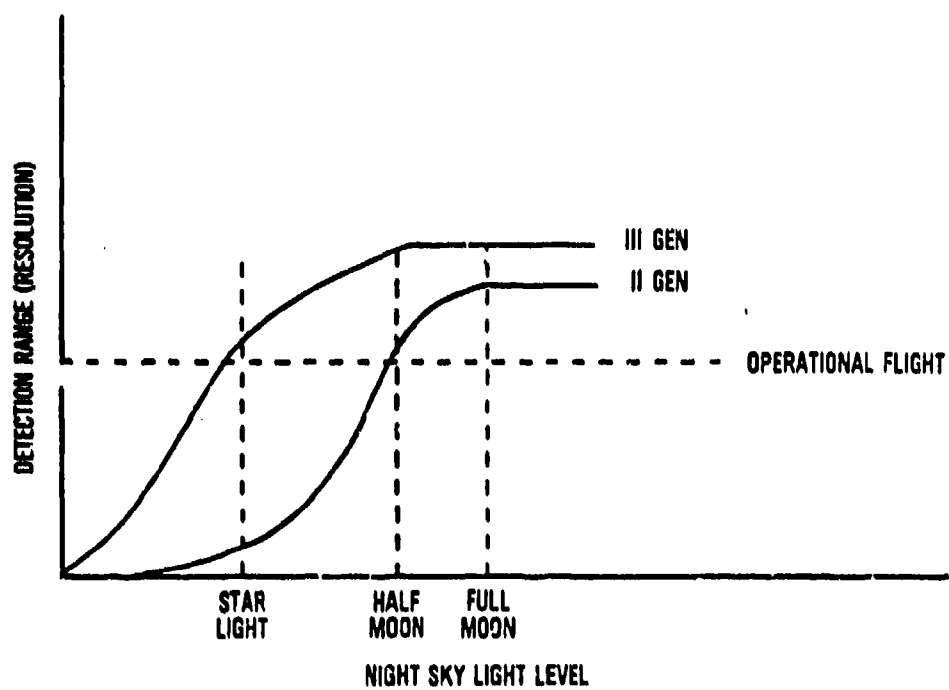


Figure 7. Image intensifier tube comparison.

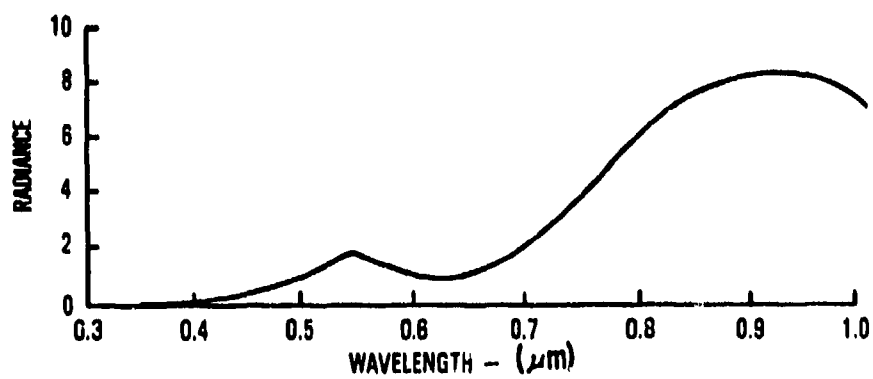


Figure 8. Spectral distribution of night sky (starlight).

The AN/PVS-5A* and ANVIS NVG used for testing were in good operating condition with recently installed power cells (2.7v lithium batteries) to ensure optimum response. Before data collection began, each subject was instructed in the proper aligning and focusing techniques for both NVG. The first test was to measure the best binocular visual acuity for each subject with each of the NVG. Binocular rather than separate monocular testing was chosen because it realistically represented actual field use. Measurements were made by appropriately positioning a Snellen eyechart, consisting of black letters on a white background, at 20 ft so that it was illuminated only by the ambient starlight. Great care was taken to ensure that no inadvertent artificial lighting was present. Data were recorded in standard Snellen notation (e.g., 20/100, 20/200) and later converted to minimum visual angle resolvable (MAR).

Secondly, to field test stereopsis with the NVG, a modified Howard-Dolman protocol was devised using two military jeeps and walkie-talkie radio communication. The jeeps were positioned in a structureless field at a distance of 140 yd. This distance was chosen because it effectively equated the visual angle subtended by a jeep, after allowing for the decreased resolution of the NVG, with that of a test Jovel in the standard laboratory Howard-Dolman test. Subjects were to indicate when the moving jeep, which had been initially displaced, was aligned with the stationary jeep. The starting point of the displaced jeep was randomized and care was exercised to ensure that no cues from interposition or motion parallax were present. The range of linear displacement from two trials was obtained and used to calculate the angle of disparity (η) per the aforementioned equation. Range was used in this measurement because the subjects were required to signal when alignment was first accomplished and they were not allowed to "overshoot" or bracket the reference jeep. Thus, a range of alignment error was obtained that compensated for the relatively long length of the jeeps.

Finally, each subject was asked to view, alternately with each NVG, into a valley from atop a hill of elevation 1500 ft and look at a scene that was essentially a semi-paved road meandering through scrub grassland and small trees (Fig. 9). The area viewed varied from 0.2-3.0 miles away from the observers, and a jeep was positioned somewhere on or near the road under complete blackout conditions. This jeep was randomly moved after each trial per radio communication. The subjects were subsequently asked to choose, subjectively, which NVG they would prefer for use in navigating through the valley and detecting targets. A complete record of their responses and comments was maintained.

*The AN/PVS-5A NVG used in our testing were slightly modified from normal to increase their field-of-view. This modification, however, should have no significant effect on the parameters measured herein.

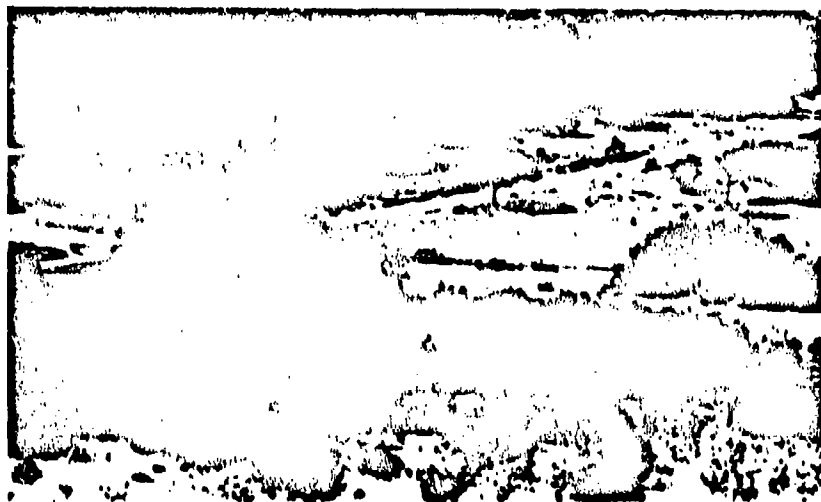


Figure 9. Photograph of the area viewed in the subjective comparison part of the experimental testing. A jeep can be seen in the center of the picture.

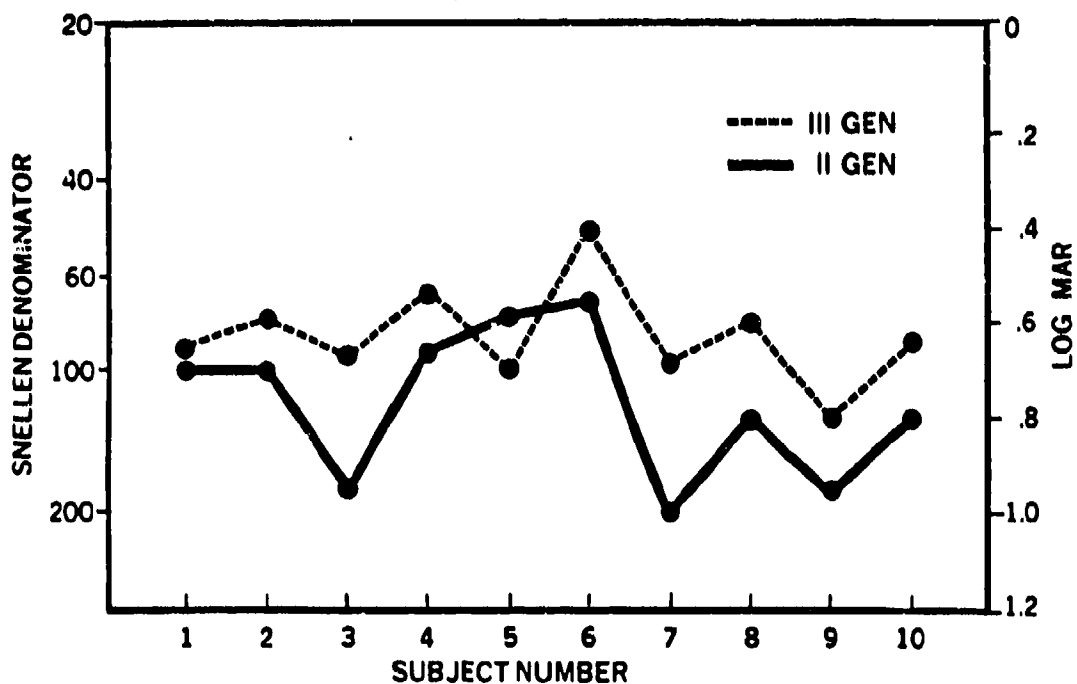


Figure 10. Visual acuity in Snellen fraction and minimum visual angle resolvable (MAR) per each subject with each NVG.

RESULTS

The subject information and baseline clinical data are shown in Table 2. The subjects ranged in age from 24 to 61; there were 7 males and 3 females; 6 of the subjects wore a visual correction; all had 20/25 binocular visual acuity or better (1.25 minimum angle resolvable); and possessed a relatively normal range of stereopsis on the Howard-Dolman apparatus, except for one subject. Subject 9 was not used for stereoscopic testing because she had a small angle strabismus.

The experimental visual acuity data obtained from field testing of the AN/PVS-5A (II GEN) and ANVIS (III GEN) NVG under the desired starlight conditions are shown in Table 3. The data are specified as a Snellen fraction, denoting best binocular visual acuity (BVA) and minimum visual angle resolvable (MAR). A plus sign indicated that one letter in the next smaller line could be read; a minus sign indicated that one letter of the specified line was missed.

As can be seen in Figure 10, 9 out of 10 subjects could see better with the ANVIS NVG, although the amount of difference was variable. The mean BVA values of the 10 subjects were $20/124 \pm 53.8$ for the AN/PVS-5A and $20/86 \pm 19$ for the ANVIS. In terms of MAR, the mean values were 5.2 ± 2.2 and 4.4 ± 1.0 in seconds of arc, respectively. Statistical analysis (Wilcoxon Test) revealed that the median difference was significant at the .01 level. Linear regression comparing the NVG BVA with the baseline BVA showed correlation coefficients (r) of .56 and .21 for the AN/PVS-5A and ANVIS, respectively (Fig. 11). Neither of these values were statistically significant at the .05 level.

The data from the field Howard-Dolman testing are shown in Table 4. Data were obtained on only 6 of the 10 subjects because of logistical problems and time constraints. The linear range of displacement of the 2 jeeps from 2 trials is recorded in feet and then converted to angle of disparity (η) in seconds of arc. As can be noted, the η values with the NVG are roughly equivalent to the baseline η values. It must be remembered, however, that the measurement method was changed in the experimental testing in order to compensate for inherent differences from the baseline apparatus. Figure 12 illustrates that 4 of the 6 subjects had a smaller η (i.e., better depth perception with the ANVIS, and 2 subjects had a smaller η with the AN/PVS-5A). The mean data revealed $\eta(\text{AN/PVS-5A, II GEN}) = 11.0 \text{ sec} \pm 5.4 \text{ sec}$ and $\eta(\text{ANVIS, III GEN}) = 7.4 \text{ sec} \pm 4.3 \text{ sec}$. The median difference was not statistically significant at the .05 level (Wilcoxon Test). In addition, the linear regressions comparing the baseline η values to the experimental η values (Fig. 13) were $r = -0.9$ and $r = .33$ for the AN/PVS-5A and ANVIS respectively. Thus, no statistically significant correlation between these two parameters was present (.05 level).

The results of the subjective comparison of a scene with each NVG are shown in Table 5. Six out of 10 subjects preferred the AN/PVS-5A over ANVIS for viewing the aforementioned scene in the valley. This is quite surprising and will be addressed in the Discussion.

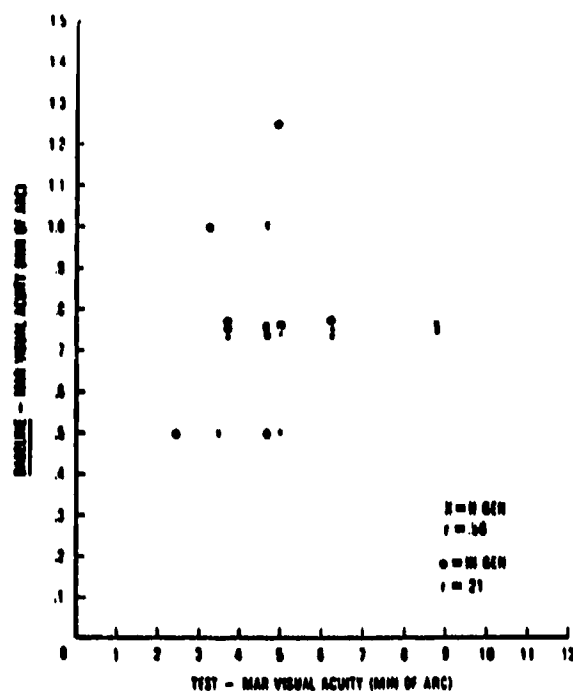


Figure 11. Experimental test visual acuity as a function of baseline visual acuity with night vision goggles. MAR is the minimum visual angle resolvable in terms of minutes of arc; r is the correlation coefficient.

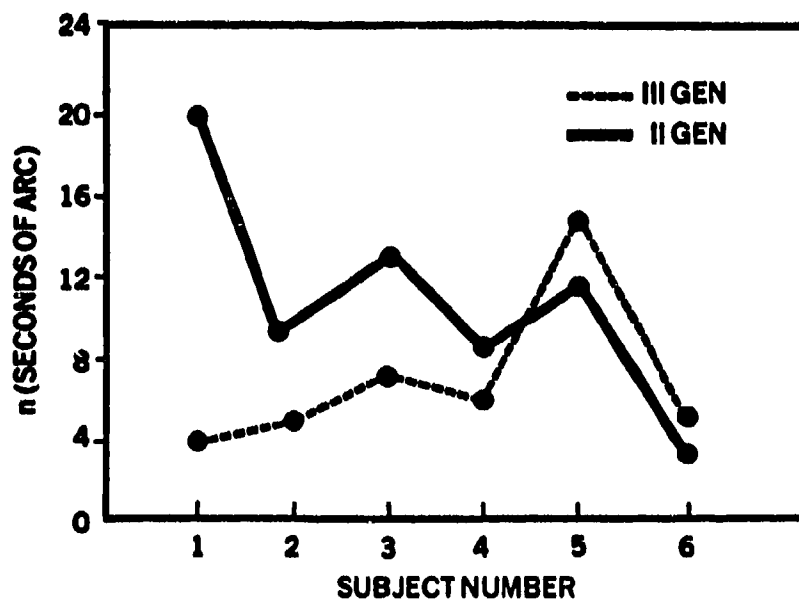


Figure 12. Depth perception (stereopsis) in seconds of arc for each subject with each of the NVG.

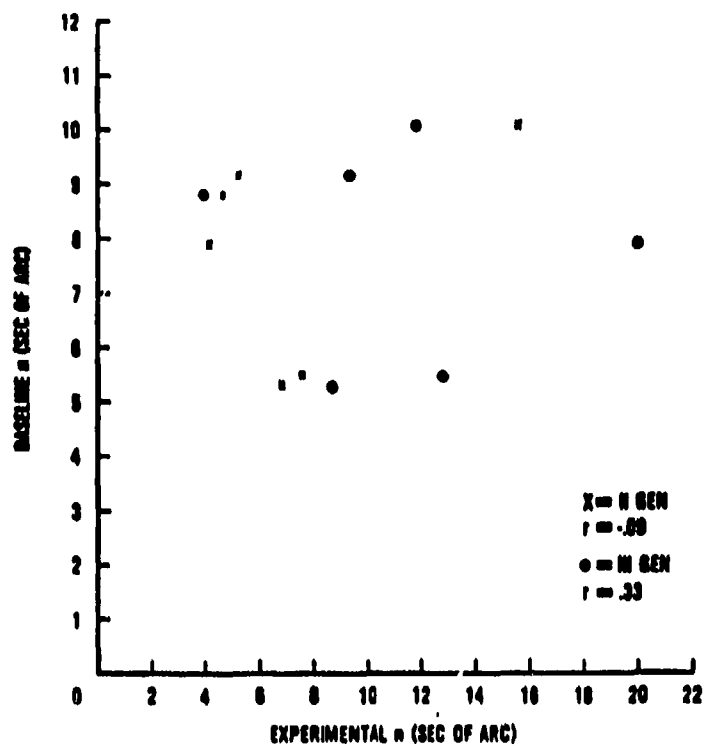


Figure 13. Experimental test stereopsis as a function of baseline stereopsis with night vision goggles. The stereoscopic angle of disparity (n) is in seconds of arc; r is the correlation coefficient.

TABLE 2. BASELINE CLINICAL DATA

SUBJECT	SEX	AGE	BVA ^a	MAR ^b	SPECTACLES ^c	IPD ^d	H-D ^e
1	M	36	20/10	0.50	NO	65	7.9
2	F	31	20/15	0.75	YES	58	9.2
3	M	38	20/15	0.75	YES	64	9.5
4	F	31	20/20	1.00	YES	64	9.1
5	M	34	20/15	0.75	NO	64	10.1
6	M	38	20/10	0.50	NO	66	8.8
7	M	61	20/25	1.25	NO	62	8.6
8	M	45	20/15	0.75	YES	66	7.7
9	F	28	20/15	0.75	*YES	62	37.0
10	M	24	20/15	0.75	YES	65	3.6

* Subject No. 9 wore contact lenses.

^aBest binocular visual acuity.

^bConversion to minimum angle resolvable.

^cWhether visual correction (spectacles) was worn.

^dInterpupillary distance.

^eMean error score in seconds of arc on the Howard-Dolman depth perception apparatus.

TABLE 3. EXPERIMENTAL DATA SHOWING THE BINOCULAR VISUAL ACUITY (BVA), MINIMUM ANGLE RESOLVABLE (MAR), AND LOG (MAR) OBTAINED FOR EACH SUBJECT WITH THE AN/PVS-5A AND ANVIS NVG.

SUBJECT	AN/PVS-5 (II GEN)			ANVIS (III GEN)		
	BVA	MAR	LOGMAR	BVA	MAR	LOGMAR
1	20/100	5	.70	20/100+	4.7	.67
2	20/100	5	.70	20/70-	3.8	.58
3	20/200+	8.75	.94	20/100+	4.7	.67
4	20/100+	4.7	.67	20/70+	3.3	.52
5	20/70-	3.8	.58	20/100	5	.70
6	20/70	3.5	.54	20/50	2.5	.40
7	20/200	10	1.0	20/100	5	.70
8	20/100-	6.25	.80	20/70-	3.8	.58
9	20/200+	8.75	.94	20/100-	6.25	.80
10	20/100-	6.25	.80	20/100+	4.7	.67
\bar{X}	20/124	6.2		20/86	4.4	
S.D.	53.8	2.2		19.0	1.0	
S.E.	17.0	0.7		6.0	0.3	

TABLE 4. EXPERIMENTAL DATA FROM THE MODIFIED HOWARD-DOLMAN TESTING OF DEPTH PERCEPTION.

SUBJECT	AN/PVS-5A (II GEN)		ANVIS (III GEN)	
	LINEAR ^a	n ^b	LINEAR	n
1	80	19.9	17	4.2
2	42	9.3	24	5.3
3	52	12.8	31	7.6
4	35	8.6	28	6.9
5	48	11.8	64	15.7
6	15	3.8	19	4.8
7	45.3	11.0	30.5	7.4
S.D.	21.4	5.4	17.2	4.3
S.E.	8.7	2.2	7.0	1.7

^aThe linear range of alignment in feet.

^bThe corresponding angle of disparity in seconds of arc.

TABLE 5. SUBJECTIVE PREFERENCE FOR II GEN (AN/PVS-5A) OR III GEN (ANVIS).

SUBJECT	PREFERENCE
1	III
2	III
3	II
4	II
5	II
6	II
7	II
8	III
9	II
10	III

DISCUSSION

As fully anticipated, the testing of man/NVG visual acuity revealed that, under these experimental conditions, the ANVIS (III GEN) NVG gave better resolution than the AN/PVS-5A (II GEN) NVG. In terms of MAR, the ANVIS possessed superior mean visual acuity by a factor of 1.4 (6.2 to 4.4 min. of arc). This performance difference is statistically significant at the .01 level (Wilcoxon Test). From the clinical point of view, this difference represents a greater than one-line improvement on the Snellen eyechart which is clinically significant as well.

In essence, the data show that man/NVG visual acuity is 20/100- with the AN/PVS-5A and 20/80- with the ANVIS at this low ambient light level (10^{-5} mL). It is well known that normal photopic (daylight) vision is 20/20 or better; and scotopic visual acuity under starlight conditions is 20/400 or worse (12). This means that the NVG greatly increase visual acuity over normal scotopic levels but they do not, under these experimental conditions, improve vision to normal daylight levels. However, the NVG are extremely impressive in their enhancement of night visual acuity.

No correlation was found to exist between the baseline BVA and field BVA with the NVG. This most probably is a result of subject variability from lack of experience in using NVG. It is certainly not illogical to assume that a correlation would exist between standard clinical visual acuity and BVA with NVG. It is recommended that the next phase of our NVG investigation involve testing of experienced NVG users to determine if this theory is correct.

A previous study (16) had shown that stereopsis was reduced with NVG, purportedly because of the decreased resolution. Accordingly, this factor was effectively neutralized by our aforementioned methodology; and, as can be noted in Tables 2 and 4, the field test stereopsis values were roughly similar to the baseline values. Unfortunately, our comparative testing of stereoscopic depth perception which used a field-improvised Howard-Dolman modality was somewhat inconclusive. Performance was judged by the range of disparity (n) in the alignment of 2 jeeps at a distance of 140 yd. Although 4 of the 6 subjects had smaller n values, hence more accurate alignments, with the ANVIS than with the AN/PVS-5A, the difference in the mean values was not statistically significant. Logically, it could be assumed that the ANVIS would provide better stereopsis than the AN/PVS-5A. As shown in Tables 1 and 3, the ANVIS has better resolution capabilities; and it has been shown that stereopsis and visual acuity are intimately related (17). The fact that no significant difference was found may have been the result of several deficiencies in the experiment.

First, the sample size was limited; only 6 subjects were tested because of scheduling, weather, and logistical problems. A larger sample size would have been much more appropriate for statistical analysis. Secondly, the large amount of intersubject variability was undoubtedly related to the lack of experience in use of NVG by the subjects. Each photocathode tube (barrel) has 2 focusing knobs which means that each NVG must be adjusted 4 times to obtain proper focus and binocular balance. Even though each subject was briefed

before the experiment on proper adjustment of the NVG, it is quite conceivable that a binocular imbalance from unequal focusing could easily occur. It is well known that a binocular imbalance has an extremely detrimental effect on stereopsis (18). Thirdly, the fact that stereopsis was not actually being used in the experimental paradigm has to be considered. Stereopsis is believed to be relatively unimportant for judging the depth of objects over 200 m away (12). With the reduced visual acuity inherent to the NVG this limiting distance is located closer to the observer, which makes it near our testing distance of 140 yd. Even though great care was taken to ensure otherwise, the so-called monocular cues (e.g., image size, motion parallax, interposition, relative brightness, etc.) were possibly the predominant cues for judging depth with the NVG. However, appreciation of depth by using only monocular cues should still be easier with the ANVIS because of its improved resolution, gain, and sensitivity. Therefore, the fact that a statistical difference was not found is probably more an artifact of the other limitations of this experiment (i.e., too small of a sample size, and the subjects were not experienced in NVG use). Also, these same limitations were most plausibly responsible for the lack of correlation between the baseline stereopsis data and the NVG field data.

The most surprising result from this experiment was the subjective comparative testing. Tables 1, 3, and 4 solidly indicate that the ANVIS should outperform the AN/PVS-5A. Yet, Table 5 shows that 6 out of 10 subjects preferred the AN/PVS-5A device for viewing the scene previously described. The reason unanimously given for this seemingly paradoxical response was the fact that a road meandering through the valley could not be seen with the ANVIS NVG but could be seen with the AN/PVS-5A NVG. All subjects agreed that visual resolution was sharper and the images brighter with the ANVIS devices. However, not being able to see the roadway in this situation would be extremely detrimental to reconnaissance and navigation, thus their responses.

The cause of this phenomenon was not easily surmised; but after examining the scene personally and looking at the spectral response curves of the AN/PVS-5A and ANVIS photocathode tubes (Fig. 3), a plausible explanation was found. The reason that the roadway could not be seen by the ANVIS device was that the photocathode tube was equally sensitive to the road and its immediate surrounding foliage. Thus, there was no contrast gradient between the road and its surroundings to allow visual discrimination. This is undoubtedly due to the enhanced response of the ANVIS in the red and IR end of the spectrum. The semipaved road surface was probably weakly reflecting starlight from the night sky, which contained a great deal of red and IR wavelength (Fig. 8). The ANVIS tube greatly intensifies this light so that a bright output was obtained which apparently blended in with the output from the surrounding terrain. The terrain and foliage were reflecting both mid- and long-visible wavelengths that also elicited a bright response from the ANVIS tube. Accordingly, there was no detectable difference in contrast between the road and the surrounding area; hence, the subjects were unable to discriminate the presence of the road with the ANVIS.

The AN/PVS-5A, on the other hand, could discriminate the roadway because its photocathode tube is not as sensitive to the weak red and IR that the road reflected. Hence, the radiation reflected from the road surface did not elicit a response from this tube so it was seen as essentially dark. But the surrounding terrain and foliage were brightly visible to the AN/PVS-5A tube because its peak sensitivity is in the midvisible wavelengths. Thus, the road was visible as seen through the AN/PVS-5A NVG because of the contrast gradient that existed between it and the surrounding area. In effect, you could detect the presence of the roadway because its photocathode tube was not sensitive to the road, but was sensitive to the surround. Conversely, you could not see the roadway with the ANVIS NVG because its photocathode tube was equally sensitive to the road and surroundings; hence, no contrast difference could be discriminated.

Obviously, this problem with the ANVIS could be significant in navigation and target detection using roads and highways as guides. Admittedly, it would only occur in unique situations of ambient illumination and terrain; but, its potential impact on night missions deserves further investigation.

Finally, several comments from our subjects as to mechanical problems with focusing knobs and loose tube connections were received. These will not be discussed here because the two NVG that were used in this experiment were preproduction models that had been used very rigorously in the past. Assurances were given by the manufacturers that actual production models will incorporate several improvements to prevent these problems and increase durability.

CONCLUSION

Under starlight illumination:

- 1) Binocular Visual Acuity (BVA) with the AN/PVS-5A (II GEN) and ANVIS (III GEN) NVG was 20/124 and 20/86, respectively. This represents a big improvement over normal scotopic levels but is not equivalent to daylight standards.
- 2) Binocular visual acuity was statistically and clinically better with ANVIS than with AN/PVS-5A.
- 3) There was large variability in the stereopsis data presumably because of subject inexperience. Stereopsis was slightly worse with the AN/PVS-5A than with the ANVIS; however, no statistically significant difference was present.
- 4) Standard clinical measures of BVA and stereopsis showed no correlation with field NVG performance measures of BVA and stereopsis.
- 5) Situations may exist in which ANVIS NVG wearers will not be able to detect some terrain features that AN/PVS-5A NVG wearers would be able to detect.

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